From the Author

On Unity of Function in Organized Beings. By William B. Carpenter, M. R. C. S., Senior President of the Royal Medical Society, and President of the Royal Physical Society, Edinburgh.*

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There are few things more interesting to those who feel pleasure in watching the extraordinary advancement of almost every department of knowledge at the present time, than the rapid progress of philosophical views in sciences which have hitherto been too much confined to mere observation. The insulated facts which have been gradually collected by various labourers in the vast fields of comparative anatomy and physiology, are now made the basis of generalisations alike important from their extensive range, and interesting from the unexpected nature of the results to which they frequently lead; and though the application of the laws thus obtained may sometimes appear forced, and inconsistent with the usual simplicity of nature, further investigation will generally shew that the difficulty is more apparent than real (frequently arising solely from our own prejudices), and that it is in many cases the result of that combination of unity and variety by which is produced the endless diversity and yet harmony of forms so remarkable in the animated world.

The object of the present essay, which has been partly suggested by Dr Barry's valuable papers in the last two numbers of this Journal, is to carry out to particulars some of the general principles there laid down, with the addition of others which had previously suggested themselves to me. It is far from my present intention to enter into a critical examination of those papers, more especially as they have in view the laudable object of exciting the attention of English physiologists to a branch of study which has by no means received from them that consideration which its importance demands.

The time has long gone by when similarity in function and external form were considered sufficient for the recognition of analogies between organs; anatomists are now aware of the

* The above essay was read as a communication to the Royal Medical Society, 14th April 1837.

necessity of resting their comparison upon the elementary structure of organs, their connections with each other, and the changes they undergo during the progress of their development. Neither of these grounds of judgment can, I think, safely be trusted to alone; whilst, combined with each other, they furnish a body of evidence which is quite irresistible. The truth of these observations will, I trust, appear in the sequel; but I might, in the mean time, adduce in illustration the mode in which the true character of the wings of insects is to be ascertained.

If we pass in review the various means by which the locomotive organs of different classes of animals have been placed in relation with the resisting or impelling powers of the atmosphere, we shall observe a community of function, and a general similarity of external form, concealing a total difference of internal structure. In most cases, however, we may remark that the wing or other organ of propulsion, however it be constructed, is only a variation from the usual form of a corresponding part in the neighbouring groups; since "nature, in effecting a new purpose, is inclined to resort to the modification of structures already established as constituent parts of the frame, in preference to creating new organs, or such as have no prototype in the model of its formation." The question, therefore, naturally arises with regard to the wings of insects, whether they are to be considered as new organs, superadded to those which are found in the adjoining classes, and in the early stages of their own existence, or whether they can be shewn to be the result of an extension or increase of development on the part of some structure already present, although perhaps assuming a different form. We shall then first inquire what inference may be drawn respecting the real nature of the wings of insects from their anatomical structure. They may be readily shewn to consist of a fold of external membrane, extended upon ribs or nerves, which are principally formed of *tracheæ* connected with those in the interior of the body. It is only recently that the circulation of fluid has been observed in the wings. Carus describes it as visible in the pupa of many species, but he does not seem to have detected it in more than a few cases after the last metamorphosis. My friend Mr Tyrrell of Exeter, in-

formed me, however, about two years ago, that he had witnessed it in many perfect insects, especially the common housefly, if examined sufficiently soon after its emersion; and I have since had several opportunities of confirming his observations, which have, I believe, been presented to the Royal Society. The truth appears to me to be, that the circulation goes on as long as the wing continues to grow, but ceases when it has arrived at its full size; and this view coincides with the fact that slight injuries of the wing are not repaired in adult insects. The question has been much agitated, whether the circulation takes place in distinct vessels, or whether the fluid passes along the interstices of the membranes forming the wings. Analogies would certainly lead to the belief that distinct vessels exist; and it is easy to explain the difficulty of detecting them in the wing after it has become dry, from the fact that when no longer distended by fluid, they collapse and become shrivelled, so that a transverse section of a rib shews only one canal, that of the trachea, which is kept open by its elastic spiral filament. Mr A. Pritchard of London, pointed out to me a few months ago, however, a wing in which three tubes were distinctly visible in each rib. This structure is exactly analogous to that which exists in the gills of aquatic insects, and hence Oken, followed by Blainville, termed the wings *aërial gills*, an idea which, however ridiculed by succeeding writers on entomology, will, I think, ultimately appear to be supported by the strictest analogy in structure, situation, and development.

The branchiæ of water insects plainly resemble the wings in being composed of expansions of the tegumentary membrane spread out upon nervures formed by tracheæ and vessels. Sometimes the membrane is continuous, so that the gills assume a foliaceous appearance, like that of the wings, but in other cases it is divided, so that the branchiæ more resemble the filamentous tufts of the nereis. The elementary structure is the same, however, in both cases. The position of the branchiæ is constantly varying; sometimes they are attached to the thorax, sometimes to the abdomen, but in every case they have an important relation with the movements of the animal, and are frequently the sole organs of progression with which it is furnished.

From the *structure* of the wings, and their correspondence with the acknowledged respiratory organs of aquatic insects, we might infer their nature with considerable probability; we shall next briefly trace their *connections* in search of the same object. If we cast a glance at the gradual development of the organs of locomotion formed by appendices to the trunk in ascending the scale in the articulata, we shall see their first appearance in the setæ of the earth-worm, and the filamentous tufts of the nereis, the latter serving both as branchiæ and as instruments of progression. In the higher annelides, one of the setæ of each tuft is more developed than the rest, forming a long tubular-jointed appendix to each segment, which is evidently the rudiment of the leg perfected in the myriapodes. The twelve segments forming the body of the caterpillar (which may be regarded as for the time an annelide), are each provided with a pair of legs;* and these are sufficient to execute the movements which the animal requires in this stage of its existence, when the whole energies seem as it were concentrated on the nutritive system. When the adult insect emerges from the chrysalis, however, after losing for a time all appearance of external members, it is found that the nine posterior segments forming the abdomen are entirely destitute of appendages, whilst the three thoracic segments are provided not only with three pairs of legs, but with two pairs of wings attached to the second and third segments. If these wings had taken the place of the legs which disappear during the metamorphosis, there might have been some ground for considering them analogous organs; but if we contrast their position on segments which retain their legs with that of the branchial tufts of the annelides, it must, I think, be acknowledged that we thus derive from their *connections* another strong argument in favour of the view I am advocating.

It remains for us now to consider their development; and though I regard this as an important link in the chain of evidence, I cannot see that it affords more than a corroborative proof, or that we should be entitled to take up such a bold position without a firmer foundation. After the third moult, the

* I am of course speaking in this, as in other cases, of the regularity or typical form.

rudiments of wings may usually be traced in the caterpillar, assuming the form of laminæ of mucous tissue, and permeated by tracheæ;* and during the chrysalis state, their development proceeds gradually towards the form which they ultimately assume. Now, as the tracheæ permeate not only the wings but the whole bodies of insects, it is evident that this circumstance of itself assists us little; the development of the wings of some aquatic insects, however, affords us more valuable testimony. "As long as the insect dwells in the water, its rudimental wings are true water gills; but so soon as it has quitted the water, they transform themselves into air gills; for, in both cases, fluids circulate in their vessels, which doubtlessly receive oxygen from the air." †

To enter into all the arguments by which this position might be supported, and to refute the objections which may be urged against it, would lead me too far away from my present object; but I may observe, that it is only by taking an extensive view of comparative structure that we can have any hope of arriving at accurate results; and great care is necessary to dismiss from our minds all prejudice in favour of any particular mode of organization as a standard or type of the rest. Let us suppose an entomologist to form his views of the structure of animals in general from that of the articulata; he would expect to find the wing of a bat or bird constructed on the model of that of an insect; and yet he would not be acting more absurdly in maintaining that this organ is an appendage to the respiratory system in vertebrated animals (especially considering its remarkable connection with this system in birds) than many entomologists in being led by their previous acquaintance with other types of structure, to consider the wing of an insect as a modification of its leg.

In speaking of the separation existing between different groups of organized beings, it is to be recollected that the minor variations from a particular type, whether that be of a class, order, genus or species, are frequently of such a character as to approximate some of its divisions to neighbouring groups; and that, sometimes, the minor or secondary character may become so predominant as to leave us in doubt to which

* Burmeister's Entomology, p. 6. † Ibid. 442.

group any individual belongs. I might refer to the characters of the mollusca, so strongly marked in the cirrhopodes, although the latter group unquestionably belongs to the articulated series; or to the characters of the bat and bird, so strikingly displayed in the pterodactylus. Without wishing to enter into the discussion of the circular and quinarian theories, I may state my conviction that Messrs Macleay, Fries and Swainson, are perfectly correct in maintaining, that the types of each group are definitely separated from one another; but that their aberrant members (where the chain is complete) have the strongest relations of affinity. Every one must perceive that the extended researches which are at present being carried on, both in zoology and botany (and these not confined to the existing epoch, but extending to past ages) are every day contributing to fill up the links that before seemed deficient; and it is now generally regarded as the true character of a complete natural group, that it passes by almost imperceptible gradations into every adjoining one. To take the example of the cephalopodes and fishes. Although the former are universally regarded as the most developed of the mollusca, no conchologist would assume the class as the type which most prominently represented the peculiar characters of that division of the animal kingdom. In like manner, fishes, which are the least developed of the vertebrata, are far from being typical of their division. We might expect, therefore, on the principles just laid down, that the hiatus should not be very wide between these two classes; and although Cuvier was of opinion, that an impassable gulf separates the vertebrata and invertebrata, more extended research has shown, that though there may be little general resemblance in form between any fish and any cephalopod, yet there is a very gradual transition in the structure of most of the systems of these two classes. Thus the nervous system, and internal skeleton of the highest cephalopodes, may almost be placed on a level with those of the lowest cartilaginous fishes; the arrangement of their circulating apparatus is strikingly intermediate between that of the mollusca in general and that of fishes; and whilst, in their organs of locomotion, we see a beautiful adumbration of those which are characteristic of fishes, so, in many fishes we may trace the remains of those

usually regarded as peculiar to the cephalopodes.* No inferior group of mollusca presents such remarkable approximations to the class of fishes in any stage of development; and in none of them do we observe that symmetrical form and elongation of the trunk which is so prominent a feature in the structure of the naked cephalopodes.

We find among the classes which make up the sub-kingdom radiata, a still greater tendency to pass into one another; so that it is almost impossible to fix with precision the limits to each; and every botanist is aware, that however definitely even the primary divisions of the vegetable kingdom may be formed, many obstinate transgressors of their boundaries will be met with, which exhibit a very troublesome fondness for their neighbours' domains.

Dr Barry has quoted from Burmeister the very ingenious remark, that the osteozoa (vertebrata) unite in themselves the development of the nutritive system, which is characteristic of the gastrozoa (mollusca) and the locomotive apparatus of the arthrozoa (articulata). This is a beautiful confirmation of the arrangement of the invertebrata, suggested by Lamarck, who regarded the mollusca and articulata as forming two parallel lines commencing with the radiata below, and terminating in the vertebrata above; each has its own characters of elevation and degradation, and neither can be considered as in every respect superior to the other. It appears to me, that, in the nervous system of the vertebrata, we may trace the combined characteristics of those of the mollusca and articulata. In the former we find a circle of ganglia around the œsophagus, specially connected with the organs of sense, and therefore with the function of nutrition; and in their higher species, these ganglia are almost entirely supra-œsophageal, and thus pass into the cerebral ganglia of the vertebrata, whose spinal cord on the other hand (which is now generally regarded as in itself an originator of power, if not also a seat of sensation), being specially connected with the locomotive organs, is a fair representation of the double nervous column possessed by the typical articulata. Whilst, therefore, this system, being necessarily connected with all the other organs of the body, unites in the

* Cyclopædia of Anatomy, vol. i. p. 525.

vertebrata the types which it presents in the other two great divisions of the animal kingdom where it is distinctly marked, each of the other systems of the vertebrata is, I think, developed upon a single uniform plan. Thus we should not be led to look in insects with any analogies with their nutritive system, nor among the mollusca for any representation of their locomotive organs. The whole structure of the typical mollusca is devoted to the perfection of their nutritive system, and we consequently find, an asymmetrical development prevailing throughout, involving (except in the highest cephalopodes) even their organs of locomotion; and we fully recognize this asymmetrical form in the structure of the thoracic and abdominal viscera of the vertebrata in general. In the articulata, on the other hand, where the functions of animal life so greatly predominate, symmetrical development of the organs of locomotion is the prevailing character; and the form of the nutritive system is made partly to yield to this. This symmetrical development is everywhere characteristic of the organs of animal life in the vertebrata; and the resemblance forcibly occurs to us between the subdivisions of these organs in the vertebrata and the higher articulata, keeping, however, this great principle in view, that in the former, the organs of support are in part of the *neuro-skeleton*, whilst in the latter these are formed by the *dermo-skeleton*. It appears to me, therefore, that in the study of each division of the animal kingdom, we shall find parts analogous to the rest, and that the sum-total of the effect is produced by the proportional development of each system, which would seem, therefore, finally resolvable into a question of degree only.

It by no means follows, however, from this doctrine, that the whole animal kingdom is formed upon the same type, and progressively developed in such a manner that the transitory states of the higher animals furnish exact representations of the permanent forms of the lower. What is meant to be maintained is, that each organ in the progress of its evolution presents analogies in elementary structure and in degree of development (by no means necessarily in external form) with the permanent states of the same in the classes beneath; and this is again to be understood with the limitation just now expressed, which will prevent us from seeking in insects any forms analo-

gous to the nutritive system in the Vertebrata, or from looking in the Mollusca for any representation of their locomotive apparatus. Moreover, it usually happens that the development of the different systems does by no means proceed *pari passu*, and hence the embryo cannot be considered as presenting in its totality any resemblance or analogy with beings beneath it; and it is deficient in this very important faculty, the power of maintaining its own existence. But in certain cases where it is necessary that it should possess this power, it is attained by preserving such a harmony in the development of the different systems, that they shall all act in unison with one another; and the being does then present a perfect transitory resemblance to those of the class beneath. Thus it would be difficult to demonstrate that the tadpole is not a fish *pro tempore;* no naturalist would hesitate in what class to place it, if only acquainted with its early form; and the same observation will apply to the caterpillar, whose structure is altogether that of the annelides. Taking this view of the case, therefore, metamorphosis does not essentially differ in nature from those changes which every animal undergoes in the progress of its development; but the embryo is adapted for deriving its subsistence from the world around, instead of from its parent, by causing the development of all its structure to go on *pari passu*, so that each organ may harmonize in function with the rest.

Putting aside, however, for the present these extraneous but deeply interesting questions, I proceed to the proper subject of this paper, which is, to apply to *function* one of the laws propounded by Von Bar with regard to structure, namely, that,

1. A special function arises only out of one more general, and this by a gradual change.

To this law I shall add a second, that,

2. In all cases where the different functions are highly specialized, the general structure retains, more or less, the primitive community of function which originally characterized it.

The division of the changes which take place during the existence of the living animal body into the *organic* functions, and those exclusively *animal*, will answer very well for my present purpose, although, as we shall presently observe, it is only in the more specialized forms that we see them distinctly

separated. I put aside for the present that series of changes occurring alike in the plant and the animal, which have for their object the continuance of the race, not the maintenance of the individual; these will be a subject for after consideration. The organic functions being common to both kingdoms, it becomes a most interesting topic of inquiry how far the organs which perform them have the same elementary structure in each, how far the changes produced by them are similar, and how far analogy can be traced in their gradual specialization.

As all the changes which are essential to the existence of a living organism may be regarded as consisting in the assimilation of matter from without, and the liberation of excrementitious matter from within, so the two functions of absorption and excretion may be regarded as comprehending the sum of the acts by which these changes are produced. In the lowest plants and animals we find no provision for any more complicated processes. In the Algæ, for example, the whole surface is absorbent; no part more than another can be regarded as peculiarly exercising this function; every cell derives from the fluid in contact with it, or from the surcharged cells in its immediate neighbourhood, the fluid essential to its existence. In like manner we might advert to the structure of the gemmules of the Porifera and Polypifera as furnishing an example of a similar mode of nutrition in the animal kingdom; but as these beings are mere embryos, it is not perhaps fair to adduce them in illustration. We very early find in the animal kingdom a tendency to specialization of the organs of absorption, by the appropriation of a continuation of the external surface for the purpose. In the common hydra, for example, we may regard the animal as entirely composed of a stomach and its appendages; and this stomach may be regarded as simply a reflection of the tegumentary membrane *inwards*, as the experiments of Trembley sufficiently prove, by shewing the mutual convertibility of these two surfaces. We may then express the form of the absorbent portion of the general surface by such a sketch as the following (Fig. 1). Now, although we have here a decided internal stomach, we still have the tissues deriving their nutriment by *immediate* absorption, partly from the fluid within the bag, and partly from that on the exterior, as the experiments before allud-

ed to seem to prove. Here, then, is the lowest degree of specialization of the function of absorption in the animal kingdom; and perhaps we may regard the condition of the absorbent surface in the lichens as somewhat analogous to it, since in these it is generally only *one* surface that absorbs freely, namely, the one least exposed to the sun and air. The first appearance, however, of any extension of the surface for this purpose (such as we find in the radical fibres of some fungi, but more particularly in the mosses), takes place by an *external* prolongation; and we may therefore consider Fig. 2. as illustrating, in contrast with Fig. 1, what may be regarded as the type of the absorbent system in plants. The final cause of this difference in the direction of development will subsequently come to be considered.

Now, it will be remarked, that as soon as a particular part of the surface is modified for absorption, the tissues in general derive their nutriment indirectly through the medium of a circulating system, however imperfect. The organs of circulation are therefore to be regarded, not as essential to our idea of a living being, but as superadded in those cases where the transmission of fluid from one part to another has become necessary. Cuvier endeavoured to shew that the development of the organs of circulation in animals proceeds *pari passu* with that of a distinct respiratory system; I think it is evident, however, that we are to look for the fundamental cause of both in the specialization of the absorbent surface, through which the aliment is introduced which is to undergo subsequent change. We find in the mosses and fungi more or less separation of the nutritive apparatus from the rest of the plant, by a distinct axis of growth or stem; and in this we find the cells elongated in such a manner as to approach the form of vessels. In the Algæ, on the other hand, where there is no necessity for any transmission of fluid, the cells approach more to the normal spherical form; and if one part of the frond be taken out of the water, it will wither, although the rest be actively vegetating. In ascending through the scale of cellular plants, we find the absorbent system becoming more and more specialized, and the vascular communication more complete, until we find in the Phanerogamia the extremity only of the

root modified to imbibe fluid, and the nutriment rapidly conveyed by the vessels of the stem to distant parts of the plant, where it undergoes eertain proeesses of elaboration, whieh render it fit to be applied to the purposes of nutrition.

The eompound Polypifera may probably be regarded as presenting us with the first appearanee of a distinct cireulating system in animals. The motion of water through the pores and eanals of the sponges, ean scareely, I think, be regarded in this light, sinee the proper funetion of absorption does not commenee until the fluid eomcs in contaet with the soft tissuc lining these passages ; whieh have been justly compared, by Dr Grant, to the ramified roots of a plant turned inwards. It is in the Echinoderma, however, the bulk and solidity of whose tissues prevent that immediate absorption, either from thc stomach or the external surfaee which prevails in less developed animals, that we first pcreeive a eomplete vascular system ; and this is employed like that of plants in reeeiving direetly, from the absorbent surfaee, the fluid aliment, and in eonveying it to the distant parts of the organism. We are thcn to regard the stomaeh and alimentary eanal of animals as organs to whieh no analogy exists in plants ; in the latter, the nutriment is directly received from the surrounding medium, in a fluid form, no solid material being eapable of being introduced into their system until first dissolved. Their food, therefore, consists of water, holding various matters in solution ; and, I think, is eapable of being proved, that water and earbon in some forms eonstitute all that is essential to the growth of plants. They are, therefore, entirely dependent on the inorganic elements around them ; and as these are eonstantly within their reach, vegetables have no need either of organs of locomotion, or of an internal cavity to store up or prepare their food. Animals, on the other hand, being chiefly dependent upon mattcr previously organized, which ean only be procured under certain circumstances, rcquire pcculiar means of obtaining it, and a partieular apparatus for prcparing it to be introduced into the system. We cannot regard any substancc to have been so introduccd, until it shall have bcen absorbed ; and the only diffcrence betwcen the skin and thc mucous membrane in this respcct being, that the latter absorbs with the greatest

facility, it is evident, that the aliment taken into the stomach bears no different relation with the organism in general, than when applied to the exterior surface of the body. These views may appear trite and almost self apparent, but physiologists are in the habit of overlooking them.

Pursuing the development of the absorbing system in animals, and the gradual specialization of the function, we find, that, in the higher classes, the process no longer takes place by the general circulating system (as by the mesenteric veins in the Echinoderma), but that a new set of vessels is interposed which is still more peculiarly adapted for the purpose. It would seem that the earliest true lacteal vessels are found in fishes; and they possess many communications with the venous system, both in this class and in the reptiles. Nearly the same may be said of the lymphatic vessels whose office it is to perform interstitial absorption throughout the system. In the Mammalia, however, the absorbent system is still more specialized by the want of all communication with the veins, except through their terminal trunks. By thus tracing the gradual evolution of the special absorbent system from its more general type in the lower classes of animals, we arrive at a knowledge of its real nature.

Let us now study this function in another point of view, by applying to it the second general principle with which we set out. Although the roots of plants are evidently their special organs of absorption, there can be no doubt that the leaves and other succulent parts of the general surface perform this function when the former are absent, or afford a deficient supply of nutriment. In many of the epiphytal parasites, the latter are evidently only absorbing organs; and no one can have observed the effects of atmospheric or artificial moisture on a desiccated plant, without perceiving their importance. That the special function of the leaves is of a totally opposite nature, admits of no doubt; and we have here, therefore, a most interesting example of the principle, that the general surface, even in the most highly elaborated organism, retains more or less its primitive community of function. Nay, in the plant, the leaves possess a peculiar power of adapting themselves to the discharge of this office; for not only do they present a broad expanse of

permeable cuticle (I think it probable that absorption of fluid does not take place through the stomata, but by the general surface); but they extend this, when occasion requires, by the formation of numberless lymphatic hairs, which, like the radical hairs of mosses, &c., have a strong attraction for atmospheric moisture. Decandolle has remarked in his Theorie Elementaire, " That when any part of a plant cannot, from peculiar circumstances, discharge the duty appropriated to it, the function is performed, wholly or in part, by some other organ. It is evident, that this is but a result of the general principle I have above laid down; and the reason that plants differ in this respect from animals is, simply, that in the former the specialization of function is in no instance carried so far as in the latter; so that, any part of the general surface can perform, in a considerable degree, the function of all the rest. In the animal kingdom, we perceive that the external surface of most aquatic tribes forms part of the general absorbent system; but that in the inhabitants of the air, its function is partly changed, and it is rather an organ of exhalation. The experiments of Dr Edwards, however, shew the importance of cutaneous absorption both in fishes and reptiles; and the human body, in certain states both of health and disease, is greatly dependent upon it. A curious instance of the extent to which it may take place from atmospheric moisture alone, was related to me a few years ago whilst in the West Indies, by the governor of the island in which I was residing. A jockey, who had been in training for a particular race, being much depressed by thirst, on the morning on which he was to ride, drank a single cup of tea; the stimulus to the cutaneous system was so great, that he increased in weight 6 lbs., of which 5 lbs. must have been from atmospheric moisture. The facility with which absorption takes place through the lungs (which are to be regarded as excreting organs) is another example of the same fact; and I think that the present state of belief derived from experimental inquiry, with respect to the relative functions of the veins and absorbents, might have been anticipated by a knowledge of the principles I have been attempting to demonstrate.

In retracing the ground over which we have passed, we re-

mark, that in the simplest organisms, that both animal and vegetable, a permeable membrane is all the apparatus necessary for absorption; and that vessels only become requisite where the fluid has to be conducted to a distant part, either to serve for the nutrition of the system, or to undergo a change in its own constituents. We have remarked, also, that the digestive apparatus of animals is to be regarded rather as an appendage to the absorbing organs, rendered necessary by the nature of their food and mode of obtaining it, than as forming an essential part of the system.

We shall now endeavour to analyse the excretory system in a similar manner; but here we meet with greater difficulty from the increased complexity of the function. We cannot regard the rejection of the excrementitious portion of the food as a part of the function of excretion as performed by animals, any more than the reception of the food by the mouth is a part of the function of absorption. It would be better, therefore, to limit the term *excretion* to the throwing off matter which has been already assimilated. This process, which is constantly taking place in most of the tissues of plants and animals, bears a strong relation, in point of activity, with the tendency of each structure to spontaneous decomposition. Thus the bones of animals and the heart-wood of plants will exist almost for an indefinite period after the death of the individuals; and in them little change takes place during life. In the softer tissues, on the other hand, whose decomposition is so rapid after vitality is extinct, the processes of interstitial deposition and absorption are vigorously performed throughout the whole existence. Hence it may perhaps be inferred, that the power which living bodies possess of resisting the usual decomposing influences of heat, moisture, oxygen, &c., is due not so much to anything essentially different in the affinities which hold together these elements during life and after death, but to the vital actions by which every particle exhibiting the least tendency to disorganization is immediately removed, and replaced by matter newly assimilated. It is a curious fact that after *animal* life is extinct, a certain degree of *organic* life frequently remains, by which the excretory functions go on for a time; thus car-

bon is exhaled in considerable quantity from the skin for a certain period after death, perspiration has appeared on the skin, urine has been secreted into the bladder, and it is even said that the hair has grown. It is only when these excretions are finally stopped by the want of circulation, respiration, and other vital functions, that decomposition can properly be said to commence.

With regard to the excretory functions of the lower classes of plants and animals, we have very little certain knowledge. The general surface in them seems to answer all the required purposes; and the first organs of secretion we can detect in animals seem rather appendages to the digestive apparatus than parts of the excretory system. Though some may regard the function of respiration in a distinct light, I see no reason for considering it as anything else than a part of the series of changes by which superfluous matter is discharged from the system. Our present knowledge of the elementary structure of glands reduces the lungs to the same type with the liver or kidneys; both consist of an excretory duct upon the minute ramifications of which bloodvessels are distributed, a part of whose contents find their way through the permeable membrane which forms the tubes or cells; and the branches, although possessing a different form, have evidently the same "fundamental unity" of structure. In regard to their functions also, there would seem no further difference than this, that whilst the excretion by the lungs serves an important purpose, the maintenance of animal heat, that of the liver answers another object by giving assistance in the digestive process. Both have alike for their object the excretion of carbon from the system, and their functions may perhaps be regarded as in some degree vicarious.

The respiratory organs are found specially developed both in plants and animals, as soon as a particular part of the surface is set apart for absorption; and the fluid is brought to them by the circulating system before being applied to the general purposes of nutrition. In plants we always find them formed by expansions of the external surface, beneath which the fluid is exposed to the influence of the air; and this is the type

on which the brancheæ of aquatic animals are constructed, whatever may be the modifications of their form and situation. In air-breathing animals, on the other hand, the prolongation of the surfaces takes place internally, so that the air comes to meet the blood, instead of the blood being sent to meet the air. Figs. 1 and 2 therefore will equally well serve as representations of these two principal types of the development of the respiratory system. We find, however, many interesting intermediate forms, such as the pulmonary branchiæ of the Arachnida; and in tracing the development of the air-bladder of fish into the lung of the reptile, and at the same time the progressive disappearance of the gills, we have a beautiful example of the gradual change which (where the links are all within our reach) may everywhere be observed throughout nature. I think that the structure of the respiratory organs affords a beautiful illustration of the argument which might be raised on *a priori* considerations in favour of the doctrine of "fundamental unity of structure."* The function of respiration is a very simple one, and it is essentially the same not only throughout the animal kingdom, but in vegetables also, as I shall presently shew. It might be regarded then, as a necessary result of the law, which everywhere prevails throughout creation, of the attainment of every *end* by the best adapted *means*, that the essential structure of the organs should be the same where the function is the same, but that the disposition of these parts should vary with the circumstances in which that function is to be performed. I need not point out the evident correspondence of this conclusion with existing facts.

The experiments of the late Professor Bennett and Dr Daubeny, on the gaseous changes produced by vegetables, warrant (I think) the conclusion, that the disengagement of carbon, which by union with the oxygen of the atmosphere forms carbonic acid, is constantly going on, and is essential to life equally with the respiration of animals; while the fixation of carbon, which only takes place during the stimulus of sunlight, is rather analogous to the digestion of animals. The latter process in a healthy plant far more than counterbalances the other; and

* This term I derive from Dr Barry.

thus the greatest part of the solid matter of the tissues must be obtained, since it does not appear that much carbon is taken up by the roots of plants in general. The fixation of carbon, however, only takes place in the green parts of the surface; and the fungi being entirely destitute of this power, can only vegetate on decaying organised matter, which affords a regular supply of carbon to their radical absorbents, and they give out a large quantity by respiration from the general surface.—Now, although in the highest vegetables, the leaves are the principal organs for effecting the gaseous changes already alluded to, these changes take place more or less by the whole surface, and the access of atmospheric air to the roots is of great importance to the health of the individual. The functions of the spiral vessels of plants are not certainly known, but from the quantity of oxygen they contain, they would appear to partake in the process of respiration.

In tracing the gradual specialization of the respiratory system in animals, we may perceive that its perfection is marked, not by its apparent extent, but its concentration. Thus the ramified tracheæ of insects, extending throughout the whole system, afford an amount of respiration superior in proportion to that of most vertebrata; but the apparatus is evidently formed on a low type. The same might be said of that of birds, which is extended in a similar manner, and for a similar purpose. The large size of the air-cells indicates the comparatively small extent of surface actually employed for the performance of the function; whilst the minute subdivision of the lungs in the higher mammalia, and their complete enclosure in the thoracic cavity, mark the highest degree of specialization of which this apparatus is capable. In all cases, however, we may observe that the general surface retains more or less of its primitive community of function. In the soft-skinned Batrachians the experiments of Dr Edwards have well demonstrated the importance of cutaneous respiration; and similar experiments on the human body shew that the same process is constantly taking place; and it would appear that where there is much local action, as in inflammations, the quantity of carbon discharged from the skin is very much increased. It would be interesting

to investigate if this excretion like that of the liver is increased when the functions of the lungs are impeded by disease.

The exhalation of fluid is another part of the function of excretion which might be separately considered in the same manner; but my limits forbid me to dwell upon it. I must also be very brief with regard to the acknowledged organs of secretion. We find that in plants the secretions are usually formed to be stored up in the system, where they answer some purposes not well understood; a few are exuded from the surface; but it is not a little remarkable that some of the principal excretions of plants take place by the roots, the special organs of an opposite function. I am disposed to believe that this excretion, whose importance to the agriculturist is now acknowledged, necessarily results from the process of exosmose which must exist wherever endosmose is carried on; and as it would seem probable that a part of the descending sap, or of the previously formed secretions, is mixed with the absorbed fluid for the purpose of increasing its density and maintaining the endosmose, it necessarily follows that some of it must be lost in this manner. The greater activity of the vital functions in animals, and the larger quantity of the solid ingesta, require a more special provision for excretion besides that which takes place by the respiratory and exhalant systems. Accordingly we find biliary and urinary organs very low in the scale; but these are still formed upon the same general plan. We see the simplest type of their structure in the mucous crypts of the alimentary canal; and as the excretory ducts are but prolongations of the external surface, so their minute ramifications by which the gland is formed, are to be regarded in the same light. As all the glands, therefore, have the same elementary structure, and differ only in the peculiar adaptation of each to separate a particular constituent of the blood, it is a necessary result of the second law to which allusion has so frequently been made, that either the general surface or either of the special secreting organs should be able to take on, in some degree, the function of any gland whose duty is suspended; and observation and experiment fully bear out this result. The "fundamental unity of the structure" of glands has been made apparent, not only by comparing those of different degrees of de-

velopment in the same organism, but by the study of their gradual development in the animal scale.

I have now sketched an outline of the doctrine of Unity of Function with regard to the changes essential to the maintenance of individual organisms, both of plants and animals; we may next briefly direct our attention to the reproductive system, and examine how far it is from the first a special apparatus, and whether its functions are completely separated in any case from those of the nutritive organs. In tracing the development of the reproductive organs in the cellular plants, we observe that in the lowest tribes the multiplication of cells may be considered as alike the production of new individuals and the extension of the original organism; each cell is capable of maintaining an independent existence, but each is connected with those around it in forming one general structure. Where special reproductive vesicles are evolved, different from the cells which form the plant, we find that at first no particular part of the general surface is modified for their development; but in the higher algæ, the lichens, and especially the fungi, we can trace the gradual separation of the reproductive from the nutrient system. In the flowering plants we have still two modes of reproduction; the special apparatus of fructification furnishing seeds; and the nutritive system furnishing buds, which may be regarded as extensions of the original stock, or as new individuals. The doctrines of Morphology, however, prove to us that even the fructifying system is but a different form of corresponding parts in that of nutrition; and hence the separation is never complete in vegetables. In the lowest animals, we may remark a similar difficulty in fixing the precise limits of individuality; and this is a necessary result of the gradual specialization which this function undergoes in common with every other. Where distinct gemmules are formed, (which in their homogeneity resemble the spores of cellular plants,) they are at first produced from any part of the external surface, as in the hydra; but in ascending the scale we find a particular apparatus adapted to the evolution of the embryo, such as the curious ovaries of the echinoderma. As we advance, the structure of the ovum becomes more and more complex, and the analogy which its parts bear to those of the seeds of plants

is sufficiently obvious. I may, however, point out the correspondence both in structure and function, between the cotyledons* of plants, especially such as are membranous) and the temporary branchiæ, which, as is now well known, may be traced in the embryos of all the higher animals.

That the embryo of flowering plants takes its origin in a simple vesicle, analogous to that which forms the entire germ of the cryptogamia, is now well understood ; indeed, I think it would be easy to apply in detail to vegetables the doctrines of "fundamental unity of structure," which Dr Barry has shewn from the researches of German embryologists to exist throughout the animal kingdom, and which he has spoken of as applicable to organised beings in general.† One speculation I may hazard at the present time, leaving it to abler botanists to decide upon its merits. The embryo of flowering plants continues to be developed during the ripening of the seed, so that at the period of maturity the cotyledons are fully formed, and the plumula and radicle are ready to elongate themselves into an ascending and descending axis. The spore of a cellular plant, on the other hand, being a simple cell, first produces others similar to itself, and these gradually form a leaf-like expansion, such as Mirbel has beautifully shewn in the marchantia, and such as exists at a certain period in the germination of ferns also.‡ This leafy expansion it is from which the stem, roots, and gyrate fronds of the latter class originate ; and when these are fully formed, it decays away. Although the mode of the development of the stem seems in Mr Dickie's view to prevent us from regarding this leafy expansion as a cotyledon, I scarcely see how we can regard it in any other light ; since, physiologically speaking, it differs only in this, that the embryo of the fern forms it whilst maintaining an independent existence, and the embryo of the flowering plant whilst supplied with nutri-

* Where the cotyledons are *fleshy*, that is, contain a store of albumen within themselves, they evidently supply also the purpose of the yolk-bag in the ova of animals.

† I think it due to myself, however, to state, that, as far as regards the vegetable kingdom, these views were previously entertained and expressed by me, although Dr B. was, I doubt not, unaware of the fact.

‡ Magazine of Zoology and Botany, vol. i.

ment from the parent. The analogy, then, between the spore and the seed, is something like that of the tadpole and the frog, both of the former being less developed states of the latter, but modified to maintain an independent existence. Taking this view of the case, the fronds of such plants as the marchantia, which are permanent, and never develope a distinct axis of growth, must be regarded as cotyledons, and are obviously analogous to the perennial branchiæ of the lower classes of animals. It is interesting to remark that the simple cell, which is the type of the lowest plant as well as of the lowest animal, is also the type of the earliest embryonic condition in both kingdoms; and there is no more perceptible difference between the germ of a plant and an animal, than there is between those of the different classes of either kingdom.

In tracing the gradual development of the functions peculiar to animals, namely, sensation and voluntary motion, we may, I think, even here find that the special type is evolved from one more general. If the views which I have elsewhere stated be correct, it follows that the irritability of certain tissues in plants is analogous to that of the muscular fibre of animals; and that the actions immediately connected with the maintenance of the organic functions of the latter, are the direct result of external stimuli on their organism. The possession of a nervous system must, I think, certainly be regarded as the distinguishing characteristic of animals, although our means of investigation will not always enable us to detect it; but the functions of this system in the lowest classes of animals, would appear to be almost entirely confined to the conduction of impressions from one part of the organism to another. As we rise in the scale, we observe that the instinctive actions which are the necessary respondence of the organism to external stimuli, are gradually overpowered by the influence of the will; and although, as has been recently observed,* we may regard the nervous system as living and growing and carrying on its actions within the body of an animal as a parasitic plant does in a vegetable, and as not communicating any influence which is immediately essential to its organic functions, yet we must perceive (to use the words of the

* British and Foreign Medical Review, vol. iii. p. 10.

same author) " that the objects of the existence of animals require that the mental actions of the nervous system should exert a powerful controlling influence over all the textures and organs composing an animal."

The organs of sensation, when examined in the ascending scale of animals, will, I think, afford us illustrations of the same general principles. We may perceive that the special functions of sight, hearing, and smell, are rather elaborated out of the general sense of touch than superadded to it; and there would not therefore appear, *a priori*, any physiological impossibility in the fifth pair supplying a certain power of sight when the optic nerve is absent, as in the mole; and, if the phenomena of the transference of sensation should ever be indisputably established, their explanation on the same principles will be easy.

Without entering into any detail with regard to the structure of the various organs of locomotion in animals, it is easy to observe the intimate connection which exists in the lower classes of this kingdom between the exercise of this function, and those movements which are essential to the maintenance of the organic life. Thus the cilia, which in so many of the aquatic tribes are almost the sole instruments of progression, serve also to bring supplies of food to the mouth, and of water to the respiratory organs. In the higher classes we see each of these functions performed by a special apparatus, but still a connection may be traced; and I know not a more striking illustration of it than the structure of the locomotive system of birds. In this class, as in insects, a high amount of respiration has to be combined with general buoyancy of the body; and this object is attained by the general diffusion of the respiratory organs. But in insects, the principal organs of progression are merely an extension of the respiratory system; whilst in birds, a special locomotive apparatus is evolved, which still, however, retains a certain connection with the function of respiration.